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Mobile inductivity

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Abstract
A system for sampling and analyzing a material located at a hazardous site. A laser located remote from the hazardous site is connected to an optical fiber, which directs laser radiation proximate the material at the hazardous site. The laser radiation abates a sample of the material. An inductively coupled plasma is located remotely from the material. An aerosol transport system carries the ablated particles to a plasma, where they are dissociated, atomized and excited to provide characteristic optical reduction of the elemental constituents of the sample. An optical spectrometer is located remotely from the site. A second optical fiber is connected to the optical spectrometer at one end and the plasma source at the other end to carry the optical radiation from the plasma source to the spectrometer.

Keywords
Ames Laboratory, Civil Construction and Environmental Engineering

Disciplines
Chemistry | Civil and Environmental Engineering | Environmental Engineering

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United States Patent [19]

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[45] Date of Patent: Mar. 30, 1999

[54] **MOBILE INDUCTIVELY COUPLED PLASMA SYSTEM**

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[73] Assignee: **Iowa State University Research Foundation**, Ames, Iowa

[21] Appl. No.: **117,242**

[22] Filed: **Sep. 3, 1993**

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[63] Continuation of Ser. No. 770,524, Oct. 3, 1991, abandoned.

[51] **Int. Cl.**[6] **G01J 3/30**

[52] **U.S. Cl.** **356/316**

[58] **Field of Search** 356/315–316, 356/318–319, 36

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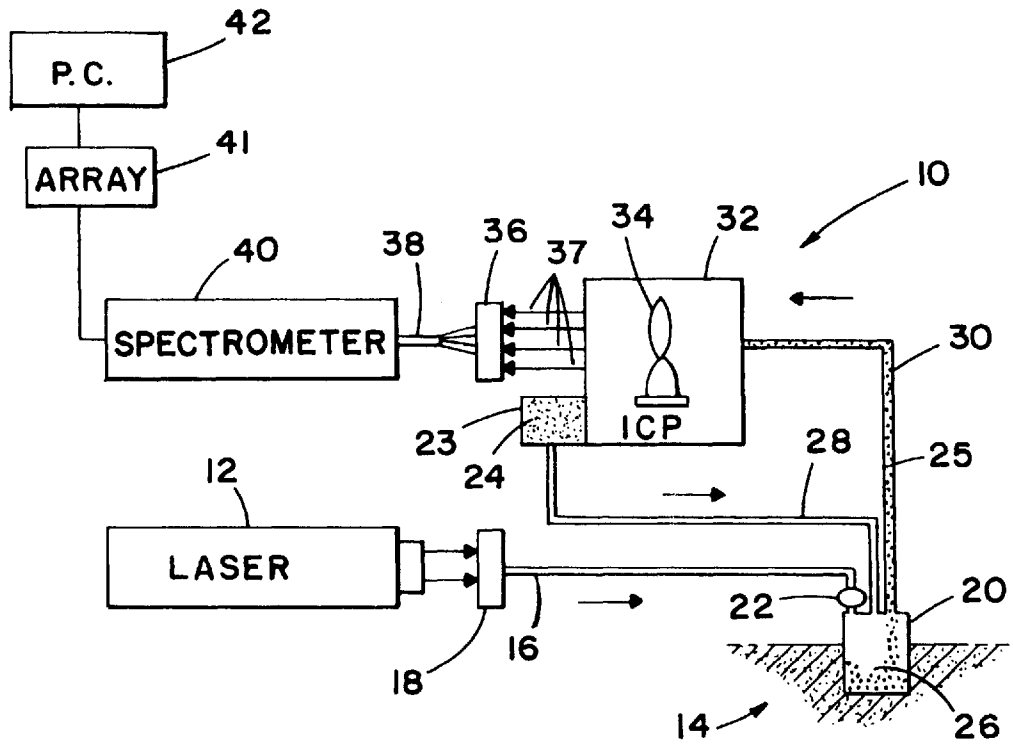
Primary Examiner—K. P. Hantis

Attorney, Agent, or Firm—Schwegman, Lundberg, Woessner, and Kluth, P.A.

[57] **ABSTRACT**

A system for sampling and analyzing a material located at a hazardous site. A laser located remote from the hazardous site is connected to an optical fiber, which directs laser radiation proximate the material at the hazardous site. The laser radiation abates a sample of the material. An inductively coupled plasma is located remotely from the material. An aerosol transport system carries the ablated particles to a plasma, where they are dissociated, atomized and excited to provide characteristic optical reduction of the elemental constituents of the sample. An optical spectrometer is located remotely from the site. A second optical fiber is connected to the optical spectrometer at one end and the plasma source at the other end to carry the optical radiation from the plasma source to the spectrometer.

17 Claims, 5 Drawing Sheets



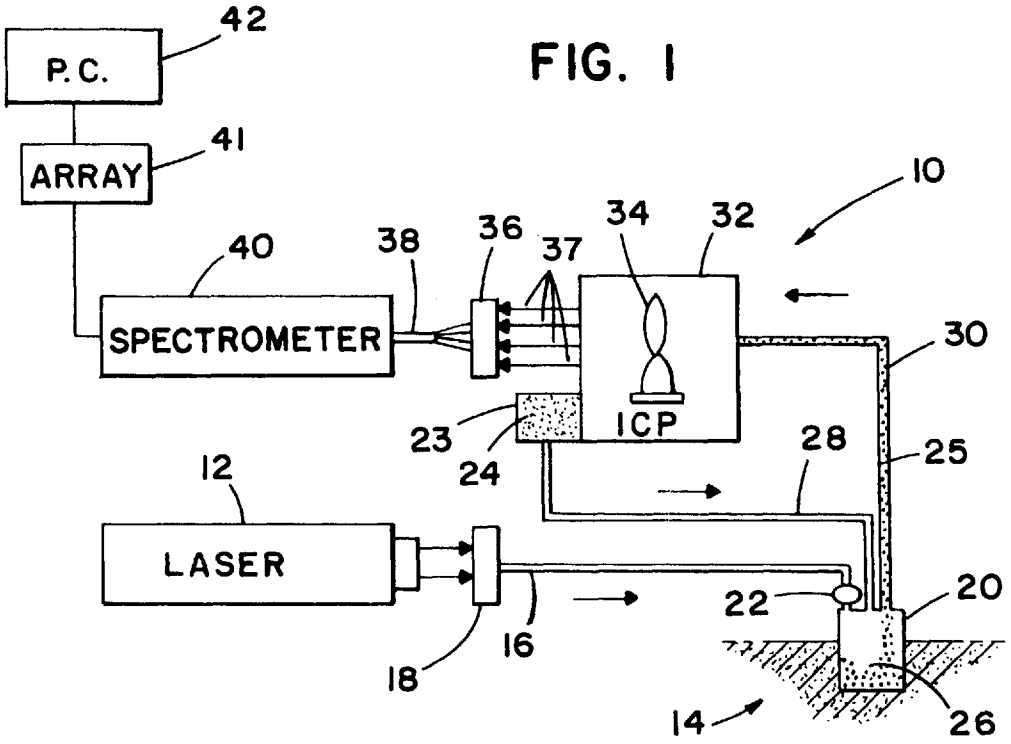
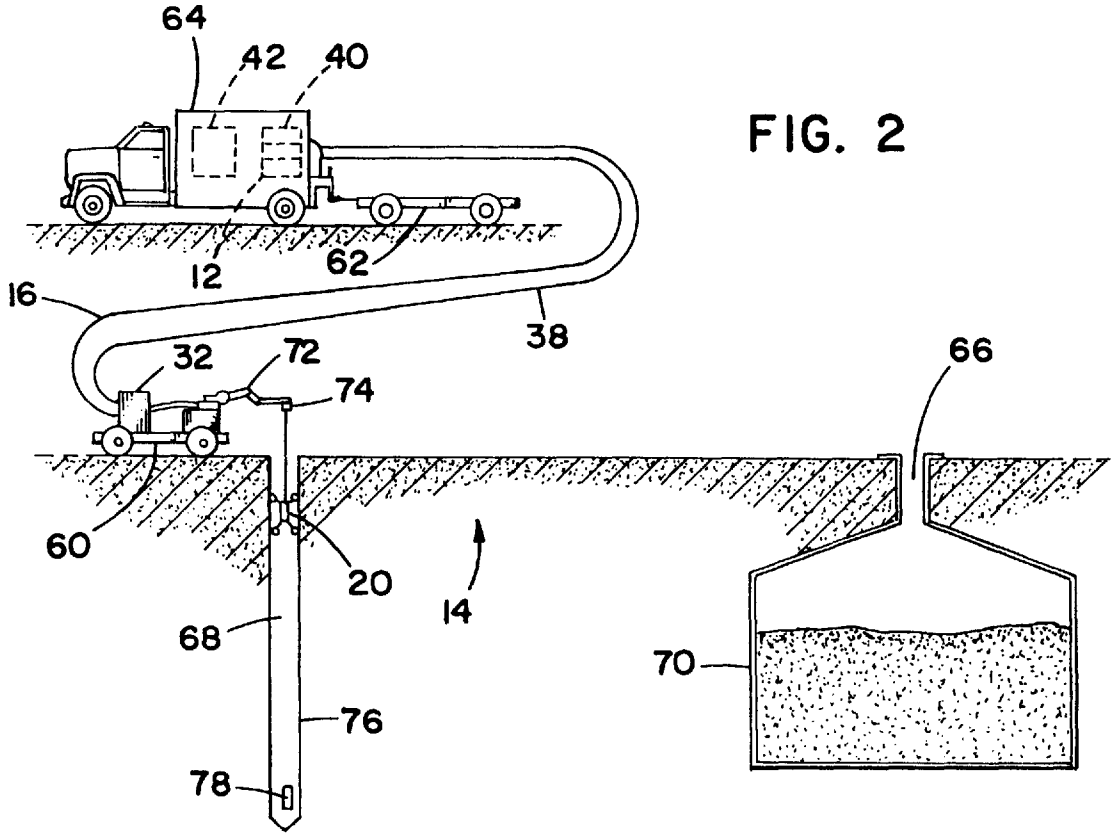

P.C.
42
ARRAY
41
40
SPECTROMETER
38
36
37
34
32
10
30
ICP
23
24
28
25
12
LASER
22
20
18
16
14
26

FIG. 1


64
42
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12
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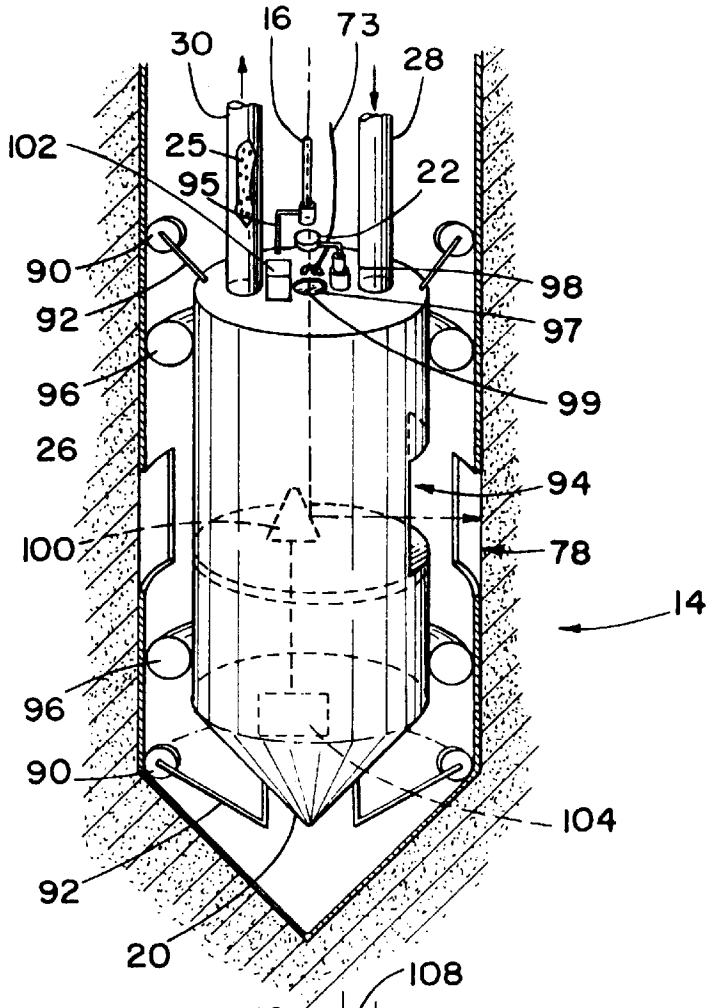
16
38
32
72
74
66
60
20
14
68
70
76
78

FIG. 2

FIG. 3


16
73
30
28
102
25
95
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98
92
97
96
99
26
94
100
78
14
96
90
104
92
20

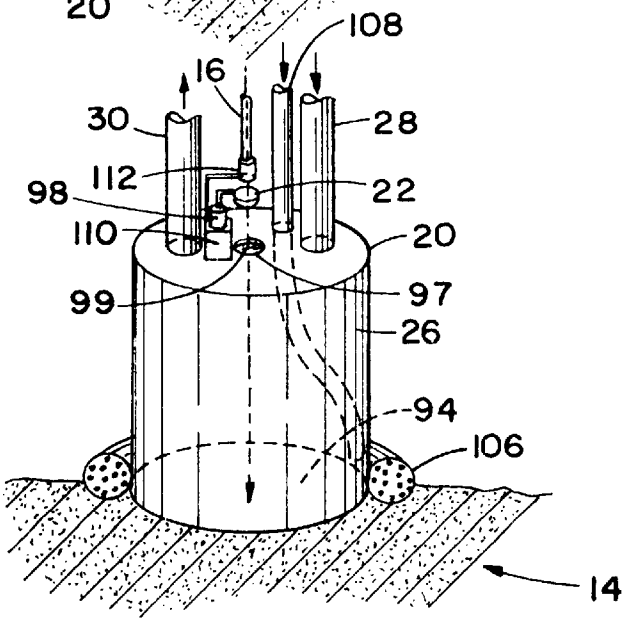
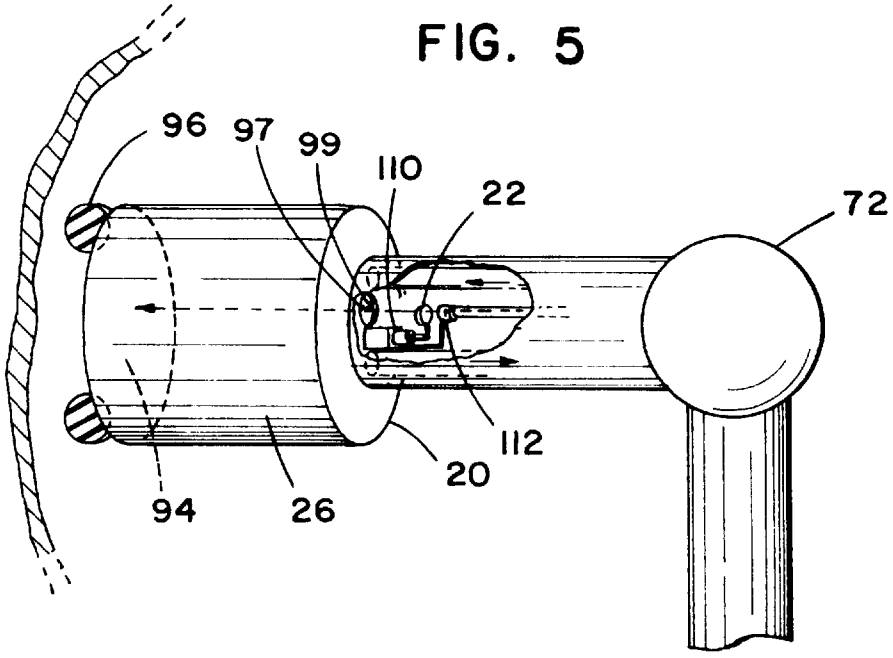

108
16
30
28
112
98
22
110
20
99
97
26
94
106
14

FIG. 4

FIG. 5


96
97
99
110
22
72
112
20
94
26

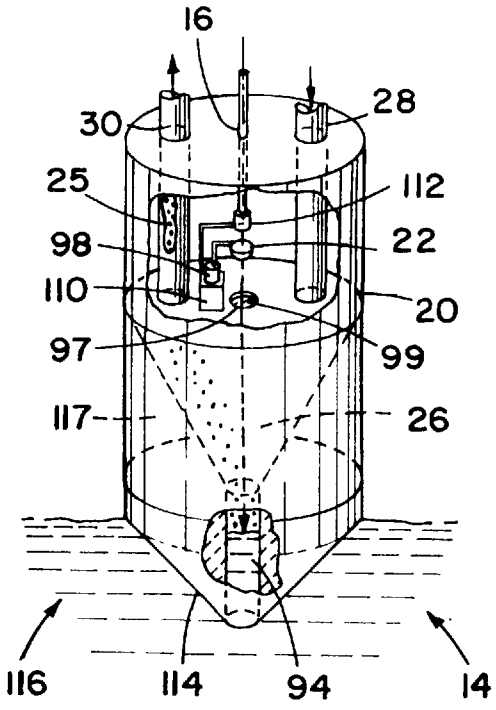
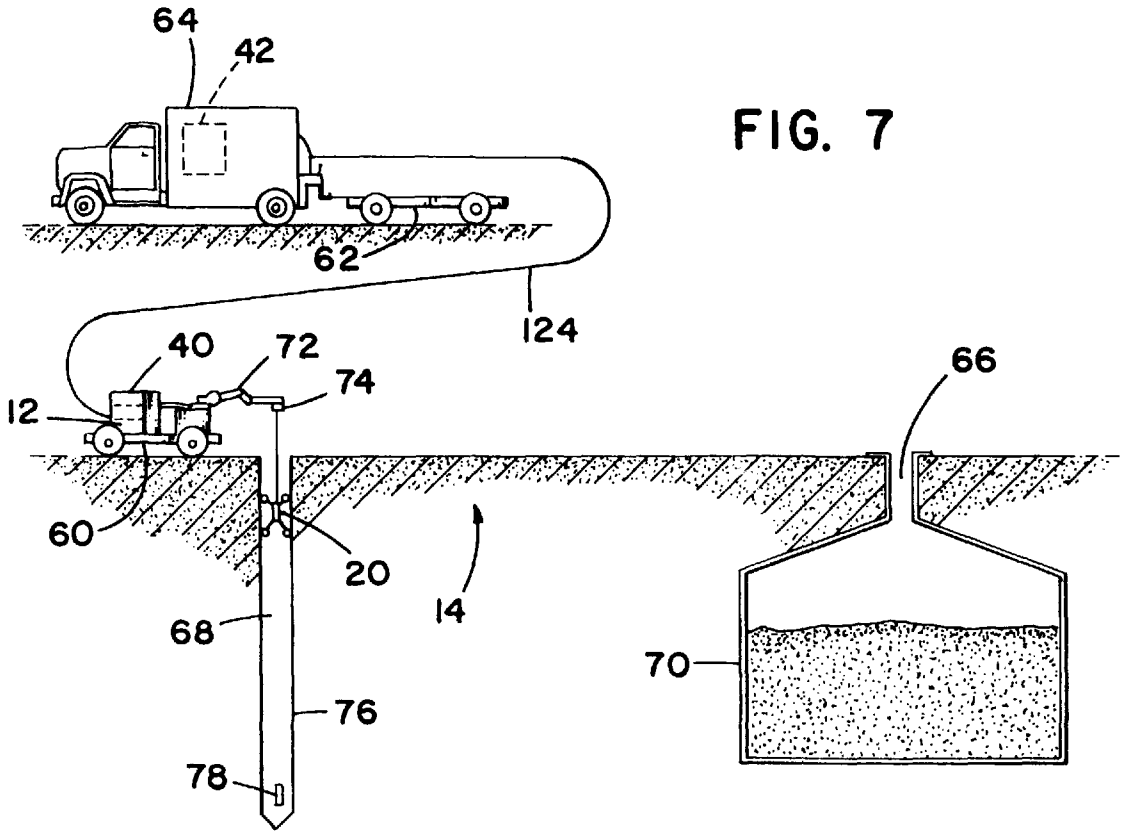

16
30
28
25
112
98
22
110
20
97
99
117
26
116
114
94
14

FIG. 6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62
124
40
72
74
12
66
60
20
14
68
70
76
78

FIG. 7

FIG. 8

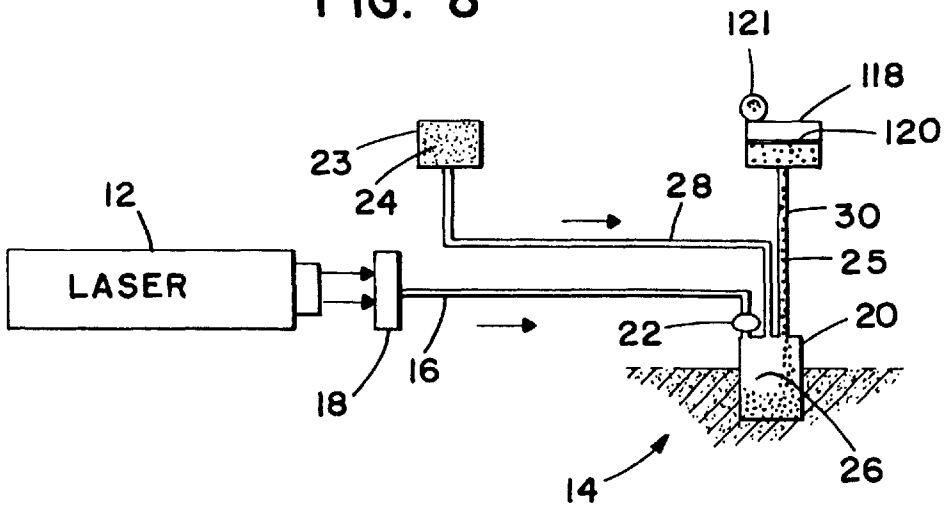
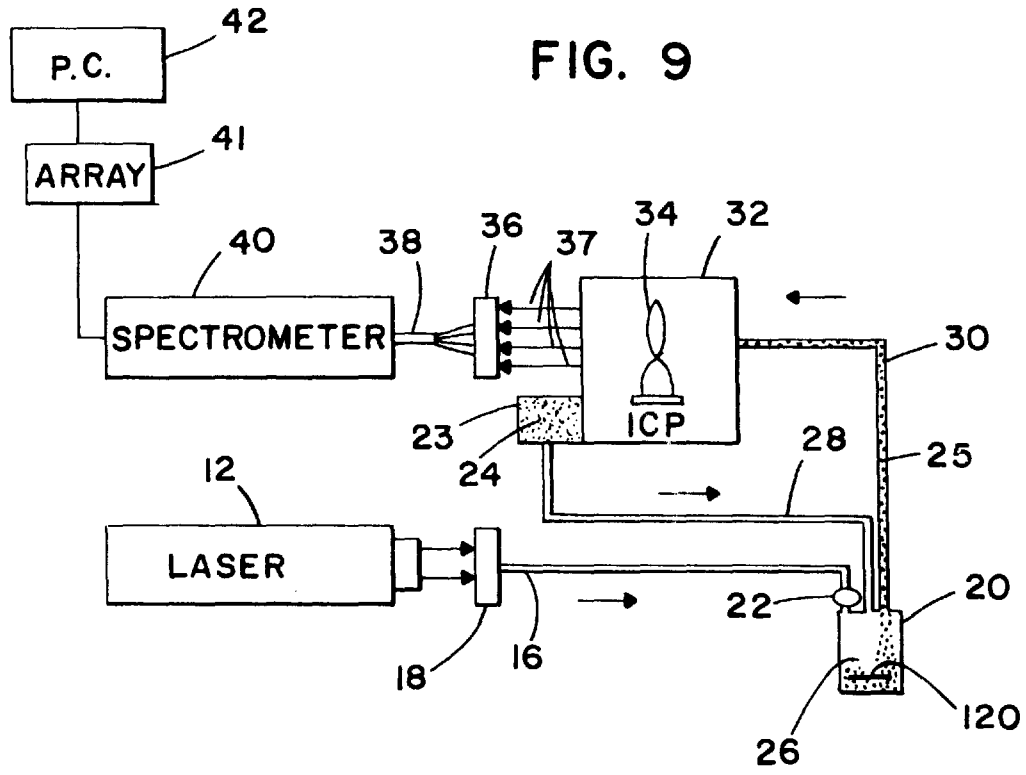

121
118
120
23
24
28
12
30
LASER
25
22
20
18
16
26
14

FIG. 9


P.C.
42
ARRAY
41
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SPECTROMETER
38
36
37
34
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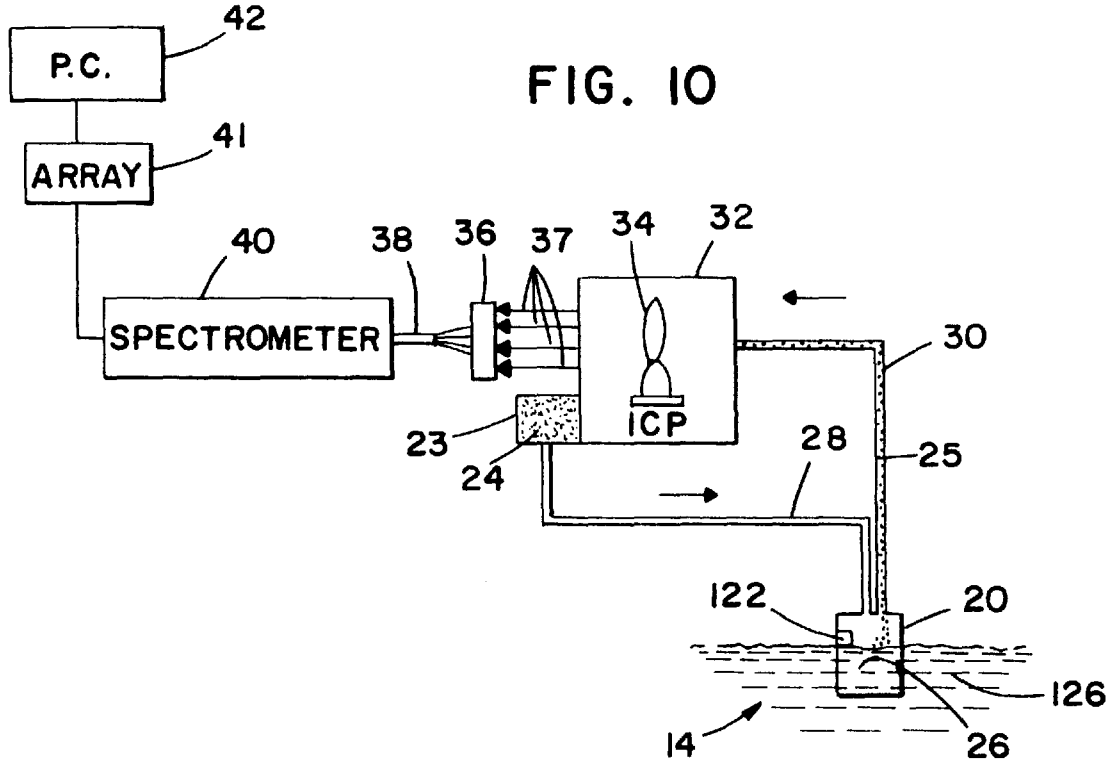
ICP
23
24
28
25
12
LASER
22
20
18
16
120
26

FIG. 10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ARRAY
41
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36
37
34
32
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ICP
23
24
28
25
122
20
126
14
26

MOBILE INDUCTIVELY COUPLED PLASMA SYSTEM

The Instant Application is a continuation of Ser. No. 07/770,524, filed Oct. 3, 1991, now abandoned.

The invention was made with support under contract with the Department of Energy Contract No. W-7405-ENG-82. The Government has certain rights in the invention.

TECHNICAL FIELD OF THE INVENTION

This invention pertains generally to the field of material analysis, and more particularly to method and apparatus for acquisition of a material sample from a remote site and subsequent analysis of the sample.

TECHNICAL FIELD OF THE INVENTION

There is often the need for sampling and analysis of dangerous or hazardous materials, or materials located in hazardous environments. Examples include sampling and analyzing the condition of soil or water at hazardous waste sites (radioactive wastes, toxic chemical dumps or contaminated structures) or of molten metals in a manufacturing foundry. Conventionally, a sample of a hazardous waste is removed from the site and brought to a laboratory for analysis. The sample must therefore be carefully extracted, transported, handled and stored in order to assure the safety of the technicians carrying out the test, as well as the public. The expense and delay entailed in extracting, handling and storing such materials, as well as the health risks, have encouraged scientists to develop alternative testing approaches minimizing these disadvantages.

BACKGROUND OF THE INVENTION

The present invention provides a method and apparatus for sampling and analyzing hazardous materials proximate the site and such that a an absolute minimum of hazardous material need be released or removed from the site.

According to one aspect of the invention, a remotely controlled mobile cart positions a probe proximate to the sampling site. A high energy wavelength laser ablates the material, forming a cloud of micron-sized particles. The particles are drawn from the sampling site by an aerosol system which employs an inert gas, such as argon. The sample particles and argon gas aerosol are injected into an inductively coupled plasma (ICP) source, which produces electromagnetic radiation which can be analyzed with an optical spectrometer.

In one embodiment, the laser source is located in a van or truck remote from the cart, with the laser beam from the source carried to the probe over an optical fiber. The inductively coupled plasma source is located on the mobile cart, with its optical output being carried over another optical fiber to an optical spectrometer located in the van or truck, from which the material analysis is obtained. In another embodiment, the laser and spectrometer are located on the cart.

The present invention also employs several unique probe structures which isolate the sampling site from the outside environment, ensuring that only the material ablated by the laser radiation is carried to the inductively couple plasma system (ICP) through the aerosol transport system. A special ceramic probe tip is employed to extract samples from molten materials.

Because length over which the aerosol system can carry the ablated sample, another embodiment collects the ablated sample on a filter media, which is taken to a remote site for analysis using the inductively coupled plasma system discussed above.

Finally, an ultrasonic or direct injection nebulization technique is used instead of the laser to produce aerosol particles from liquid materials at the sampling site to be analyzed by the ICP.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** provides a schematic illustration of the mobile inductively coupled plasma system of the present invention;

FIG. **2** illustrates one application of the mobile inductively coupled plasma system of the present invention for sampling soil at a hazardous waste site;

FIG. **3** is a detailed illustration of one type of probe of the preferred embodiment of the present invention;

FIG. **4** illustrates an alternate sealing system for a probe which obtains samples from surface soil;

FIG. **5** illustrates another alternate sealing system for obtaining material samples from hard and uniform surfaces;

FIG. **6** is a detailed illustration of an alternate embodiment of the probe to be used to sample molten materials;

FIG. **7** illustrates an alternate embodiment of the mobile inductively coupled plasma system of the present invention where the laser and optical spectrometer are located on the mobile cart;

FIG. **8** is a schematic of an alternate embodiment of the present invention where the ablated sample is collected on a filter media;

FIG. **9** is a schematic of an alternate embodiment of the present invention where the filter media is subject to ablation for purposes of analyzing the sample; and

FIG. **10** is a schematic of the mobile inductively coupled plasma system of the present invention for use in sampling and analyzing liquid materials.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** provides a simplified schematic illustration of the mobile inductively coupled plasma system **10** of the present invention. Laser radiation from an ultraviolet laser **12** is directed to the sampling site **14** through fused silica fiber rod optics **16**. Preferably, the laser provides continuous or pulsed, fixed wavelength laser radiation at at least three different wavelengths, 1064 nm, 532 nm, and 355 nm. These wavelengths are chosen to provide a range of energies as materials to be analyzed have different absorption characteristics at different wavelengths. Since current optical fibers are subject to damage at wavelengths below 350 nm and power levels of 10^8 watts/cm^2/sec., it is best to utilize laser wavelengths above 350 nm. These constraints will change with the availability of better optical fibers. As most materials absorb optical radiation in the ultraviolet, ablation is more efficiently carried out at wavelengths below 400 nm. The Lumonics Dye Laser (Hyper-Dye 300) pumped by the Lambda Physik Excimer Laser (model EMG102MSC) is known to provide laser beams suitable for use in the present invention, although the preferred system for field operation is the solid state YAG laser.

A laser focusing system **18** is provided to focus the laser output onto the optical fiber **16**, without overloading it. C Technologies fiber optics cable model SRA-6-1-20-01 is known to be suitable for carrying the laser radiation to a probe **20**, provided no more than 10^8 watts/cm^2/sec. is

applied to the head end of the fiber. As noted above, power levels in excess of this can damage the fiber. Focusing system **18** may include a filter to narrow the laser beam and reduce the power actually received by the optical fiber and a series of lenses to focus the laser radiation onto the end of the optical fiber.

As will be discussed in more detail below with respect to FIG. **3**, the probe **20** has optics **22** for focusing the laser radiation from the fiber **16** on the material to be sampled **14**. The probe **20** is generally constructed of aluminum, but other materials may be preferable to contend with different environmental conditions. An argon gas source **23** supplies argon gas **24** to a probe sampling chamber **26** through an aerosol input line **28**. The material ablated or sampled **25** by the laser radiation mixes with the argon **24** to form an aerosol which is drawn from the probe sampling chamber **26** through the aerosol output line **30** to the inductively coupled plasma (ICP) source **32**. Argon **24** is the support gas for the ICP **32**. The present invention employs an RF Plasma Products® inductively coupled argon plasma system.

As is conventional in the art, the aerosol is directed into the plasma source **34**, through an input line (not shown) to the ICP **32**. The energized sample particles are excited to provide characteristic optical reduction of the elemental constituents of the sample **25** in the form of electromagnetic radiation **37**, which is focused by a lens **36** and thereby subsequently channeled through an ICP output optical cable **38** to a remotely located multi-channel or sequential optical spectrometer **40**. To carry the optical output of the ICP **32** to the spectrometer **40**, the preferred embodiment of the present invention employs Polymicro Technologies fiber optic bundle (model PTA-LEI0019FF-030-0DP), consisting of 19 separate 200 μm core diameter fibers arranged in a round-to-linear bundle. The Acton Research Corp. 0.5 meter spectrometer (model VM-505) equipped with a 2400 grooves/mm grating has been found suitable as the spectrometer. The optical radiation dispersed in the spectrometer is detected by a multichannel diode array detector **41**. The EG&G Princeton Applied Research intensified diode array (model 1420) and diode array controller (model 1463) are known to be suitable for this purpose. Preferably, the IEEE output of the detector **41** is connected to a personal computer **42** or workstation whereby the output of the spectrometer **40** can be stored, enhanced, processed, analyzed, and displayed.

FIG. **2** illustrates one embodiment of the mobile inductively coupled plasma system **10** of the present invention. A remotely controlled mobile cart **60** is trailered on a trailer **62** behind a truck **64**. The truck **64** contains a power source for operating the components of the system. In use, the truck **64** is positioned a distance from the toxic waste sampling site **14**. The remotely controlled mobile cart **60** is then positioned proximate to the sampling site **14**, for instance a sampling bore **68** adjacent to the toxic waste storage chamber **70**, by direct visual reckoning or by use of video images relayed from a video camera (not shown) mounted on the cart **60**. The controls for maneuvering cart **60** are located in the truck **64**.

In the preferred embodiment of the present invention, the remotely controlled mobile cart **60** carries the ICP source **32**, so that the ICP source is as close to the sampling site **14** as possible, thereby minimizing the distance the hazardous material needs to be transported in the aerosol output line **30** and to keep the hazardous material away from the operators positioned in the truck **64**.

In the preferred embodiment, the aerosol tubes **28** and **30** are 0.25" in diameter, made of Teflon® or polyethylene material, and are pressurized to provide a gas flow of 1.0 liters/minute. The argon **24** is held under pressure in the argon source **23** to provide pressure to the system. The preferred embodiment of the present invention has achieved transportation of material samples **25** in the aerosol line **30** to a distance of 100 feet.

The laser source **12** and spectrometer **40** are located in the truck **64**. As explained above with respect to FIG. **1**, an optical fiber **16** carries the laser beam from the laser **12** to the probe **20**, while a second fiber **38** carries the output of the ICP **32** to the spectrometer **40**. Using the equipment specified herein, the laser beam can be carried up to 30 meters on the fiber **16**. Similarly, fiber **38** can carry the output of the ICP **32** about 30 meters to the spectrometer **40**.

The probe **20** is attached to a three-axis robot arm **72** mounted to the cart **60**, which is also controlled remotely by the operator, preferably using images relayed from a video camera mounted on the platform or even on the probe itself. In the application shown in FIG. **2**, the operator controls the robot arm **72** to position the probe **20** over the center of the sampling bore **68**. The tubes **28** and **30** and fiber **16**, a load-bearing cable **73**, and other necessary electronic cables (not shown) are wound on a spool with a winch **74**, which is remotely controlled to lower and raise the probe **20**. In the preferred embodiment of the present invention, the sampling bore **68** contains a liner **76** (shown in more detail in FIG. **3**), which can be a conventional pipe with a cut-out area, or window **78**, through which access to the sampling site **14** is obtained.

The probe **20** is lowered into the sampling bore **68** until it is adjacent to the sampling window **78**. The sampling thus proceeds with the operators at a safe distance from the sampling site **14**. When sampling is completed, the probe **20** is withdrawn from the sampling bore **68** and the remotely controlled mobile cart **60** is returned to the trailer **62** for transportation to the next site. If any contamination has occurred, it is generally limited to the probe **20** or the immediate accessories (i.e., cables, etc.), allowing relatively easy clean-up. The sample **25** itself is incinerated in the ICP plasma source **34**. If necessary, the probe **20** and accessories can be disposed of or destroyed and replaced at relatively low cost.

FIG. **3** illustrates one embodiment of the sampling probe **20** of the present invention. Alignment wheels **90** are attached to the leading and trailing edges of probe **20** by flexible support members **92**. The alignment wheels **90** allow the probe **20** to be lowered into the liner **76** without jamming. The probe **20** is lowered until a probe window **94** is aligned with the sampling window **78**. Inflatable seals **96** are filled with compressed air from a pressurized source (not shown) so as to seal the sampling window **78** and the probe window **94** from the outside environment.

The sampling process entails focusing the laser radiation carried on the fiber **16** through a convex lens **22**, which is located either inside or outside the probe sampling chamber **26**, depending on the design chosen. The fiber **16** is secured to the probe **20** via bracket **95**. In FIG. **3**, the lens **22** is mounted outside the probe **20** on a telescoping support **98** with an integral stepper motor (not shown), which allows the convex lens **22** to be positioned to focus the laser beam on the material to be sampled **14**, using stepper motor controller **102**. An Oriel stepper motor (model 18512) and controller (model 20010) are known to be suitable for this purpose. The laser radiation passes through a transparent covering **99** over the opening **97** in probe **20**, which isolates the sampling chamber **26** from the lens **22** and maintains the environ-

mental integrity of the sampling process. A special rotating polygon mirror **100** at the base of the sampling chamber **26** reflects the beam onto the material, providing x and y axis rastering across the sampling site **14**. Other approaches utilizing stepper motors configured to provide x–y and rotary motion can also be utilized. As will be discussed in more detail below, the operator monitors the intensity of the silicon spectra line generated by the optical spectrometer **40** to determine if the convex lens **22** is properly positioned to create the optimum focal length.

A variable speed motor **104** is remotely activated to rotate the polygon mirror **100**, and direct the laser radiation in a raster scanning pattern across the sampling site **14**. In the preferred embodiment of the present invention, scanning is performed at a rate of 5–10 millimeters per second. It is important that the laser radiation is sufficient to ablate the material to be sampled to create sufficiently small particles that can be transported through the aerosol output line **30**. However, localized melting of the material should be avoided, since melting can change the composition of the sample material **25**, leading to erroneous spectral analysis. Accordingly, the laser power (or wavelength) may need to be varied depending on the material being sampled. Further information on laser ablation is set forth in the paper entitled "Laser Vaporization in Atomic Spectroscopy," by H. K. Dittrich and R. Wennrich, *Prog. Analyt. Spectrosc.,* 7, 139–198 (1984), the entire contents of which are hereby incorporated by reference herein.

Argon **24** is forced into the probe sampling chamber **26** through the aerosol input line **28**. The ablated sample particles **25** become mixed with the argon gas **24** and are subsequently drawn from the probe sampling chamber **26** through the aerosol output line **30**. As discussed above, the aerosol output line **30** directs the mixture of argon gas **24** and sample particles **25** to the ICP plasma source **34**.

As soon as the laser **12** is activated to initiate sampling of a soil, the operator observes the spectrometer **40** output for signs of silicon, since silicon is present in virtually all soils. The position of the convex lens **22** in the sampling chamber **26** is adjusted, by stepping the telescoping support **98**, until the intensity of the silicon line in the spectrometer is maximized. At this point, the focal length of the laser radiation is correctly adjusted to focus the beam on the material to be sampled. Rastering can be performed during adjustment of the focus or initiated immediately after focus is achieved. By rastering, localized melting can be avoided and a relatively large sample area can be covered. In the preferred embodiment, a sample area of 1 $inch^2$ is covered during rastering. When sampling is completed, the air is released from the seals **96** and the probe **20** is withdrawn from the sampling bore **68** by the three axis robot arm **72**.

FIG. **4** illustrates an alternative configuration for sealing the probe **20** against the material to be sampled. The probe **20** of FIG. **4** is not shown attached to the cable **73** or the 3-axis robot arm **72** since some applications of the present invention will permit the probe **20** to be placed on the sampling site **14** manually. For example, where the material to be sampled is not toxic to humans. However, it will be understood by those skilled in the art that any of the probe configurations disclosed herein can be attached to a variety of devices for locomotion.

Like the embodiment of FIG. **3**, a convex lens **22** and telescoping support **98** are mounted to the top of the probe **20** for focusing the laser radiation through the transparent covering **99** to the correct focal length. Preferably, the telescoping unit **98** is mounted to a moveable base **110** with x and y degrees of freedom, controlled by stepper motor and controller **102** (not shown). The Oriel stepper motor (model 18512) and controller (model 20010) discussed above are known to be suitable for this purpose. The free end of the fiber **16** is fixed relative to the base **110** using an armature **112**, to keep it aligned over the lens as the base **110** moves. The moveable base **110** is remotely activated to direct the laser radiation in a raster scanning pattern across the sampling site **14**.

A perforated elastic tubular member, or seal, **106** is placed around the outside perimeter of the probe window **94**. The perforated seal **106** is preferably constructed of polyethylene foam or some other suitably porous material. Water is provided by a water line **108** to moisten the perforated seal **106** and soil surrounding the sampling site **14**. The moisture operates to seal the sampling chamber **26** from the outside environment.

FIG. **5** illustrates yet another method to seal the probe **20** against the material to be sampled. The probe again requires a similar convex lens **22** and telescoping support **98** for focusing the laser radiation onto the sampling site **14**. The moveable base **110** is remotely activated to move the end of the fiber **16** in a raster scanning pattern. The probe **20** is attached to the 3-axis robot arm **72** so that it can be positioned in a variety of angles. An inflatable seal **96** is provided around the probe window **94**, which is filled with compressed air during the sampling process. The configuration of FIG. **5** is intended primarily for sampling on substantially smooth surfaces, such as walls and ceilings of buildings. However, a variety of methods are available for isolating the probe chamber **26** from the outside environment during sampling.

FIG. **6** illustrates the use of the mobile inductively coupled plasma system of the present invention for sampling molten metals and alloys **116**. The probe **20** is constructed similar to that disclosed in FIGS. **4** and **5**. The convex lens **22** and telescoping support **98** are mounted inside the probe **20** to protect them from heat. As discussed above, the telescoping unit **98** is mounted to a moveable base **110** with x and y degrees of freedom to move the free end of the fiber **16** in a raster scanning pattern across the sampling site **14**.

A thermally resistant hollow ceramic probe tip **114** is mounted to the sampling end of the probe **20**. The ceramic tip **114** is used to penetrate the slag layer on the top of the molten metal **116**, thereby exposing the molten metal below. The water lines **108** provides cooling liquid to a cooling chamber **117**, which is located between the optics **22** and the ceramic probe tip **114**. Sampling occurs in the sampling chamber **26**, as discussed in detail above.

FIG. **7** illustrates an alternate embodiment of the mobile inductively coupled plasma system of the present invention where the laser **12** and optical spectrometer **40** are located on the mobile cart **60**, along with the diode array **41**. The electrical output signals from the diode array **41** are carried by cable **124** to the computer **42** in the truck **64**.

FIGS. **8** and **9** illustrate yet another embodiment of the mobile inductively couple plasma system of the present invention. As discussed above, the aerosol system (argon gas source **23** and argon gas **24**) of the present invention has achieved transportation of material samples **25** in the aerosol line **30** to a distance of 100 feet. However, the toxic or radioactive nature of some sampling sites **14** may require that the sample be transported more than 100 feet in the aerosol, or it may not be possible for the material to be easily carried on the aerosol. FIG. **8** illustrates a system were the ablated sample **25** is carried from the sampling chamber **26**

through aerosol output line **30** to a filter media chamber **118** containing a filter media **120**, which accumulates particles of the sample **25**. The filter paper **120** must generally have sub-micron sized pores to insure capturing sufficient sample **25** material. However, the pore size of the filter paper may vary depending on the material being sampled.

Argon gas **24** can be allowed to escape from the top of the filter paper chamber **118**. A meter **121** is located proximate to the top of the filter paper chamber **118** to monitor the quantity of argon gas **24** present. As the pores of the filter media **120** become clogged with sample material **25**, the quantity of argon gas **24** flowing through the filter media **120** will decrease, with a corresponding decrease in the quantity of argon **24** detected by the meter **121**. When the quantity of argon gas **24** detected by the meter **121** drops to a predetermined level, sampling is terminated.

The filter media is then removed from the toxic site for analysis. FIG. **9** illustrates a laser ablation system for analyzing the sample **25** collected on the filter media **120**. The filter media **120** is placed in the probe **20**, where it is subject to the laser ablation process discussed above.

FIG. **10** illustrates the use of an ultrasonic nebulizer to produce aerosol **25** from liquid material **126**. In principle, when ultrasonic waves from a transducer **122** of sufficient frequency and amplitude are produced, a capillary wave action is induced in a liquid medium **126**, causing the ejection of aerosol droplets from the liquid surface. The droplets, the dimensions of which are dependent on the ultrasonic frequency and physical properties of the liquid, can be produced with micron sized diameters. By synchronizing the transducer **122** frequencies and focusing the ultrasonic waves to a single point, a wave pattern should be generated with an amplitude sufficient to provide the quantities of sample **25** required for ICP **32** analysis. A low frequency, high power, ultrasonic stephorn generator known to be suitable for the present embodiment is disclosed by Fassel and Dickinson, *Anal. Chem.* 40, 1968, 247; and in U.S. Pat. No. 3,521,949. Once a representative aerosol sample **25** is generated, it mixes with the argon **24** and is transported to ICP **32** for analysis.

The nebulized liquid material **126** is drawn through the aerosol output line **30** to the ICP **32**. Sample analysis proceeds as discussed in detail above.

It will be understood that the present invention is not limited to the examples discussed above, but may be changed or modified without departing from the spirit or scope of the invention.

We claim:

1. A system for sampling and analyzing a material located at a hazardous site, the material having a surface and elemental constituents, comprising:

a portable sampling probe;

a laser source located remote from the sampling probe and producing a laser beam directed onto the surface of the material through an optical fiber, the optical fiber having two ends, a first end proximate said laser source to receive said laser beam and a second end mounted to said sampling probe so that when positioned by movement of said probe proximate the material at the hazardous site, the laser beam emitted from the second end ablates a sample of the material;

an inductively coupled plasma source remotely located from the material where the sample is ablated;

an aerosol transport system for transporting the sample from the material to the inductively coupled plasma source wherein the sample is excited by the plasma source to provide an output emission characteristic of the elemental constituents of the sample; and

an elemental constituent detector remotely located from the inductively coupled plasma source and receiving the output emission of said inductively coupled plasma source, an output of the detector providing an indication of the elemental constituents of the sample.

2. The system of claim **1** further wherein said sampling probe comprises:

a housing defining a sampling chamber in communication with said aerosol transport system, the chamber having an opening for receiving the sample; and

a lens on an adjustable support mounted to the housing, the lens interposed between said second end of said first optical fiber and the material to focus and direct said laser beam through said opening onto the material, so that said aerosol transport system carries the sample to the plasma source.

3. The system of claim **1** further wherein the sampling probe comprises a housing defining a sampling chamber in communication with said aerosol transport system, the chamber having an opening for receiving the sample, whereby said aerosol transport system carries the particles to the plasma source.

4. The system of claim **3** further including rastering means for rastering said laser beam across the material.

5. The system of claim **2** further including seal means attached to the housing proximate to said opening for engagement with the surface of the material to be sampled for substantially isolating said sampling chamber and the material from the outside environment during sampling.

6. The system of claim **3** further wherein the opening is defined on an end of said probe and the end of the probe is constructed of a thermally resistant material.

7. The system of claim **1** wherein a sample of particles is ablated from the material by the laser, and wherein the detector is an optical spectrometer.

8. The system of claim **1** further where the sampling probe includes a filter for collecting the sample of the material; and

the detector is an optical spectrometer in optical communication with said inductively coupled plasma source to receive said electromagnetic radiation.

9. The system of claim **1**, further comprising a second optical fiber having a first end proximate the inductively coupled plasma source for collecting the output emission and a second end proximate the elemental constituent detector for delivering the output emission to the elemental constituent detector.

10. A method for sampling and analyzing a material located at a hazardous site, the material having a surface and elemental constituents, comprising the steps of:

a) positioning a portable sampling probe proximate the surface of the material at the hazardous site;

b) directing laser radiation from a laser source located remote from the probe onto the surface of the material through a first optical fiber, the first optical fiber having two ends, a first end coupled to said laser source and a second end mounted to the portable sampling probe, the laser radiation ablating a sample from the material;

c) transporting the sample through an aerosol transport system from said probe to a remotely located inductively coupled plasma source; and

d) exciting the sample in the plasma source to provide an emission characteristic of the elemental constituents of the sample.

11. The method according to claim **10** further wherein the emission is electromagnetic radiation and further including

the step iof applying the emission to an elemental constituent detector located remote from the inductively coupled plasma source.

12. The method of claim **11** further including the step of applying said emission from said plasma source to said detector through a second optical fiber.

13. The method of claim **10** further including the step if raster scanning the surface of the material with the laser radiation.

14. The method of claim **10** further wherein the probe has a sampling chamber and including the step of substantially isolating said sampling chamber and the material from the outside environment during sampling.

15. The method of claim **10** further including the step of providing a thermally resistant tip on the probe for sampling molten metal.

16. A method for sampling and analyzing a material located at a hazardous site, the material having a surface and elemental constituents, comprising the steps of:

a) positioning a portable sampling probe proximate the surface of the material at the hazardous site;

b) directing laser radiation from a laser source located remote from the probe onto the surface of the material through an optical fiber, the optical fiber having two ends, a first end coupled to said laser source and a second end mounted to the portable probe, the laser radiation ablating a sample of the material;

c) collecting the sample in a filter mounted in the probe;

d) exciting the sample collected on said filter in an inductively coupled plasma source located remotely from the material to provide a characteristic emission of the elemental constituents of the sample; and

e) applying said emission to an elemental constituent detector located remote from the inductively coupled plasma source.

17. The method of claim **16**, further comprising the steps of:

a) ablating the sample collected on the filter using laser radiation; and

b) transporting the ablated sample to the inductively coupled plasma source using an aerosol transport system.

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